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None

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(54) Phase change mechanism

(57) A phase change mechanism is made up of a stack disc shaped elements (40) each having cut-outs which are shaped to define a central continuous central portion (42), an outer continuous rim (46) and non-radial spokes (48, 50) extending from the central portion (42) to the rim (46), all spokes being canted in the same sense so that movement of the central portion (42) towards and away from the plane of the rim (46) serves to cause a rotation of the rim (46) relative to the central portion (42).

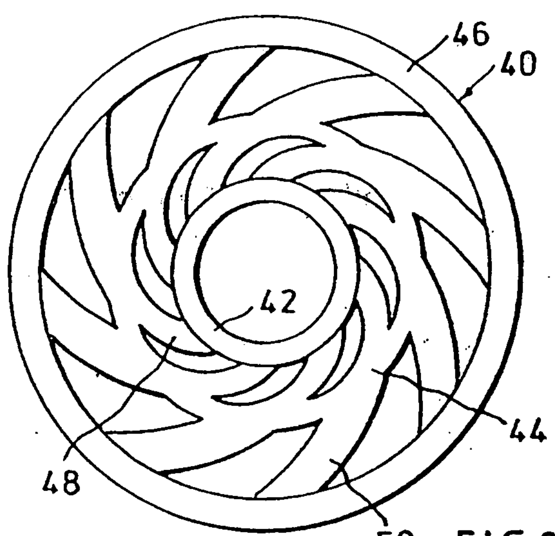

FIG.2.

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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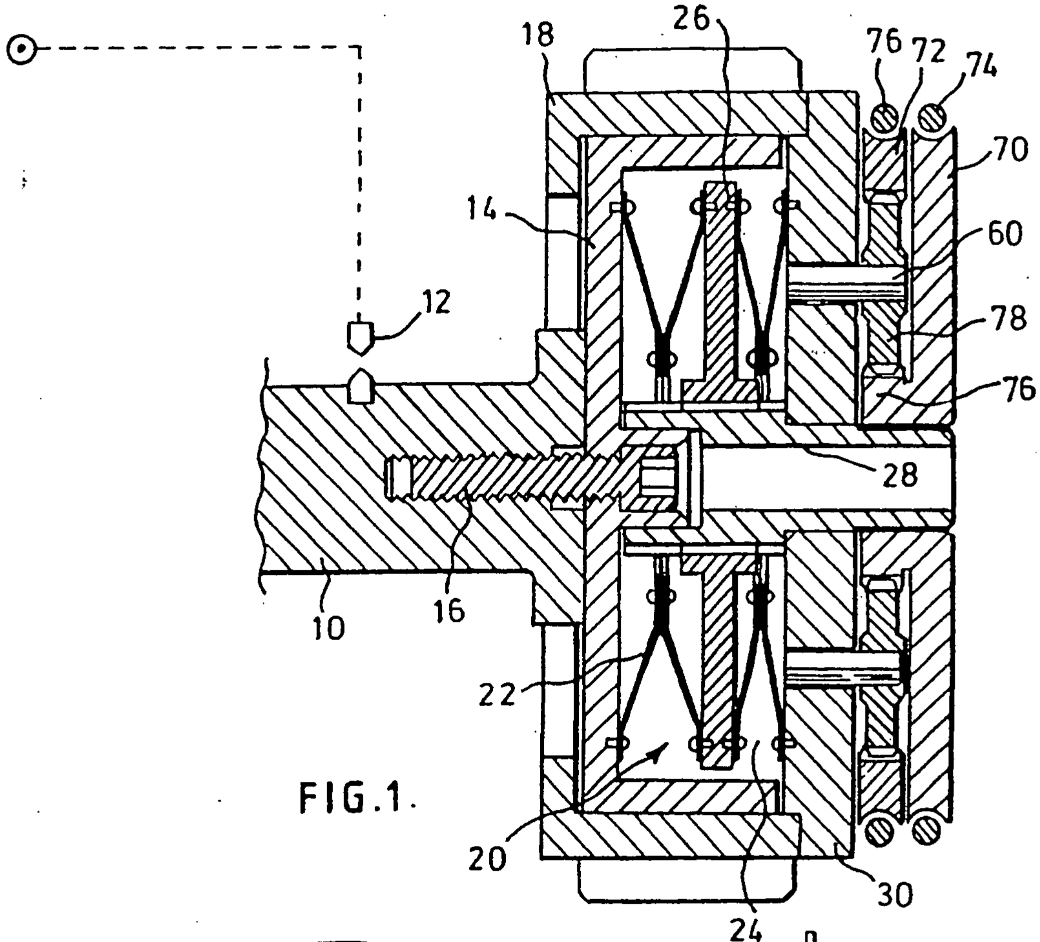

FIG.1.

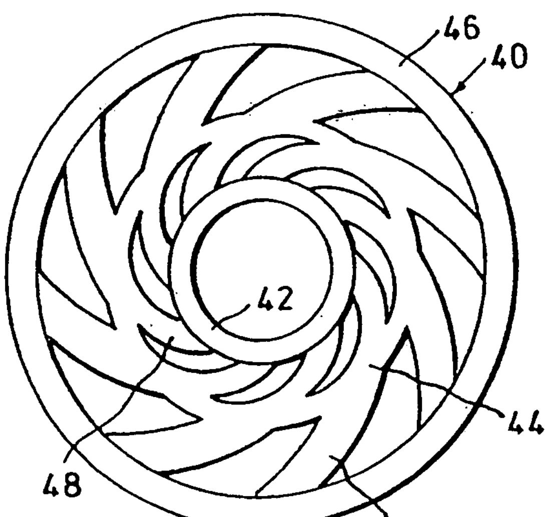

FIG.2.

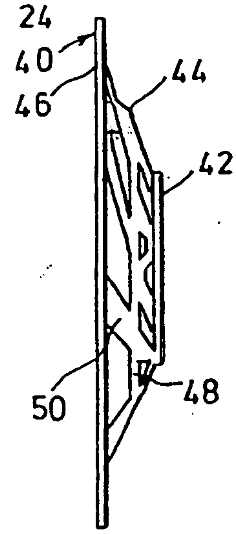

FIG.3.

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PHASE CHANGE MECHANISM

The invention relates to a phase change mechanism for varying the phase of a driven member relative to a drive member. The invention can be used for the camshaft of an internal combustion engine and in particular to varying the relative phase of opening and closing of the inlet and exhaust valves in a dual overhead camshaft internal combustion engine.

The optimum times for opening and closing the inlet and exhaust valves in an internal combustion engine vary, inter alia, with engine speed. In any engine with fixed angles for opening and closing the valves for all engine operating conditions, the valve timing is a compromise which detracts from the engine efficiency in all but a limited range of operating conditions. For this reason, control systems have been proposed which vary the valve timing during engine operation.

Various proposals have been made for adjustment of the camshaft phase angle relative to the crankshaft but these systems have all been complex on account of the need to withstand the considerable torque fluctuations experienced by a camshaft during normal operation. The system must also supply the force required to rotate the camshaft against the resistance offered by the valve springs which need to be compressed.

It has been proposed in the prior art to employ a linear actuator to set the desired phase shift. Such systems rely on converting the linear movement of the actuator into a rotary movement of the camshaft relative to its drive pulley or gear. One such example has been to include a helical gear on the camshaft and to move the helical gear axially to cause the phase of the camshaft to change.

In a more recent proposal (GB Appln. No. 8818680.4 filed by the present Applicants on 5 August, 1988), of which the present invention can be regarded as an improvement, an axially displaceable spider is connected by ball jointed lever arms to the camshaft and to the drive pulley which once again brings about a phase change as it is moved axially.

The phase change mechanism in the above patent application, is expensive and difficult to manufacture and assemble on account of its complexity and the number of parts which it comprises.

According to the present invention, there is provided a phase change element for a phase change mechanism which comprises a disc having cut-outs which are shaped to define a central continuous central portion, an outer continuous rim and a plurality of non-radial spokes extending from the central portion to the rim, all spokes being canted in the same sense whereby movement of the central portion towards and away from the plane of the rim is operative to cause a rotation of the rim relative to the central portion.

As compared with the phase change mechanism of Patent Application 8818680.4, the central portion can be seen to be analogous to the spider and the non-radial spokes to the ball jointed link arms. However, in the present invention, the movements which required ball joints in the prior proposal are accommodated by deflection of the material of the disc. Thus the entire phase change element can be made in a plate of one piece—construction requiring no assembly and eliminating all wear as there are no relatively movable parts. Other advantages of such a one piece construction are the avoiding of any source of backlash and with this the removal of any source of noise and chattering.

All these advantages do, however, invoke a penalty in that the degree of phase change that can be brought about by a single disc is fairly restricted, typically 1°. This is on account of the fact that the torsional rigidity of the element would be unacceptably reduced upon excessive deformation of the disc and there is also the risk of permanently deforming the disc through plastic flow at the ends of the spokes.

To mitigate this problem and provide a phase change mechanism which can afford a greater degree of phase adjustment, a plurality of discs are stacked and connected to one another alternately at their rims and their central portions. In such a stack of elements, care should be taken to orient the discs correctly, to ensure that their phase changes are added and not subtracted.

Phase change elements can be cascaded not only axially but also radially. By this it is meant that a single disc can be divided by cut-outs to define several annuli connected to one another by spokes canted in the same sense, each intermediate annulus constituting the rim of an inner phase change element and the central portion of a surrounding outer phase change element. In the preferred embodiment, each disc has an inner central portion, an outer rim and a single intermediate annulus thereby defining two concentric phase change elements.

The discs can either be flat or dished in their unstressed state. It is preferable for a phase change mechanism to have two stacks of discs, arranged on opposite sides of an actuator, one stack being under load when the other is relieved of load. This minimises the actuating force required to bring about a change of phase, and makes for a more compact arrangement of the discs as the overall mechanism dimensions do not change as the actuator moves.

The invention will now be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a phase change mechanism, and an actuating system therefor, incorporated into the drive pulley of a camshaft,

Figure 2 is a plan view of a disc which forms one element of the mechanism shown in Figure 1, and

Figure 3 is a side view of the disc shown in Figure 2.

The illustrated phase change mechanism is intended for changing the phase of an engine camshaft relative to the crank shaft. The camshaft 10 is generally conventional and is not shown in full in the drawings. A position sensor 12 is mounted on the camshaft 10 in order to provide position feedback for control of the actuating system.

A hub 14 is secured to the camshaft 10 by means of a bolt 16. The coupling between the hub 14 and the camshaft 10 may rely exclusively on friction, in the interest of continuous setting or a key may be provided between the two, if preferred to avoid accidental slippage. The drive pulley 18 which is driven by a timing belt or a timing chain is freely journalled for rotation about the outer periphery of the hub 14, by means of sliding or rolling bearings (not shown).

The coupling of the hub 14 to the pulley 18 is made through a phase change mechanism 20 which is made up of two stacks 22 and 24 of disc elements, each as later described by reference to Figures 2 and 3, arranged on on each side of an actuator 26. The actuator 26 is screwed onto a threaded spindle 28 by means of which it

can be moved axially. The end discs of the stack 22 are secured to the hub 14 and the actuator 26, while the end discs of the stack 24 are secured to the actuator 26 and a cover 30 fixed to the pulley 18.

Each stack is formed of discs 40 as shown in Figures 2 and 3. These are discs punched out of spring steel, typically 1 mm thick and have the shape illustrated. Each disc has a central portion 42, an intermediate annulus 44 and an outer rim 46. The central portion 42 is connected to the intermediate annulus 44 by canted spokes 48 and the intermediate annulus 44 is in turn connected to the rim 46 by spokes 50 canted in the same sense as the spokes 48. If the blank from which the disc is punched is initially flat, then movement of the central portion 42 out of this plane, as shown in an exaggerated manner in Figures 1 and 3, will result in a rotation of the rim by a small amount, typically 1°.

Because of the limited phase change possible with only a single disc, these are stacked by connecting them alternately at their central portions and at their rims so that the phase changes are cumulative. Such connected can be effected by riveting or spot welding or by interlocking engagement sufficient to prevent relative rotation of the individual discs under torque.

It is preferable for the blanks to be initially dished and to force the central portion into a coplanar position with the rim to bring about a phase change. In Figure 1, if all the discs are initially dished and pre-loaded, then in all positions of the actuator 26, the total load is constant and all the discs are constantly under compression tending to force them together at their rims and at their central portions. This construction enables interlocking engagement (such as by teeth or crenelations) to be used for the coupling of the discs.

The actuating system for the actuator 26 comprises two reaction members 70 and 72 each associated with a respective brake band 74 and 76. The reaction member 70 is a wheel fast in rotation with the actuator spindle 28. When the wheel 70 is braked by its band 74, it slows down the rotation of the spindle 28 and axially displaces the actuator 26 to bring about a phase shift in one sense of the camshaft 10 relative to the drive pulley 18.

The second reaction member 72 is the ring gear of a planetary gear set comprising a sun gear 76 and planet gears 78. The sun gear 76 of the planetary gear set is secured to the spindle 28 and can conveniently be formed integrally with the reaction member 70. The planet gears journalled on pins 60 secured to a cover plate 30 fastened to the drive pulley 18. It can be seen that the drive pulley 18 and the hub 14 together form a self-enclosed and self-supporting assembly that can be mounted on the camshaft 10 as a complete sub-assembly using the bolt 16.

If the brake band 76 is applied to brake the second reaction member 72, when the planet gears 78 are rotated by the pulley 18, through the cover 30 and their pins 60, they will drive the sun gear 76 and hence the spindle 28 faster than the speed of the actuator 26 thereby axially displacing the actuator 26 to bring about a phase change in the opposite sense of the pulley 18 relative to the cam shaft 10.

In the absence of braking, there is no tendency for either reaction member 70, 72 to rotate at a speed different from that of the actuator 26 and consequently release of the two brake bands will maintain the prevailing setting of the phase angle.

The torque for causing a phase change is in all cases derived from the engine output power and this affords ample power to permit very fast setting of the phase angle. Furthermore, the minimum number of engine cycles required for a given phase change is constant over the entire engine speed range. Of course, the minimum time required for a given phase change to be achieved occurs under maximum braking of the reaction member and should this rate of phase change be excessive then it can be reduced by applying the brake bands 74 and 76 more gently and allowing some slippage.

There is no simple direct relationship between the operation of the brake bands and the resulting phase shift. If two position settings, determined by end stop, will not afford sufficient control, then one may control the actuating system by a form of negative position feedback in which the actual phase of the camshaft is measured and compared with its desired phase to develop an error signal. The error signal, depending on its sign, is then applied to one or other of the two brake bands to set the value of the phase at the desired level. It is for this reason that a position sensor 12 is included in the camshaft 10. Of course, it is possible to incorporate some form of position sensor on the hub 14 in order to avoid modification to an existing camshaft 10.

If desired, the interior space defined by the hub 14, the pulley 18, the cover 30 and the spindle 28 can be totally contained using suitable seals and can be filled with grease or oil so that the entire device may be self-lubricating. The moving elements outside this sealed enclosure, are only under light load because of the very high gear ratio of the spindle thread so that they may be lubricated by grease or by being made from a self lubricating plastics material.

The brakes for the reaction members may be continuous brake bands, as can be found in automatic gearboxes, brake shoes operated by a calliper of the twin leading or single leading variety, or disc brakes. In all cases, the brakes are to one side of the reaction member and not in line with the camshaft, so that the length of the engine (the most critical dimension) is not increased.

The preferred embodiment described above offers the important advantages that by mere substitution for the existing timing pulley, the described assembly can convert an existing engine into one benefiting from variable valve timing. The space requirements of the assembly are little different from those for a conventional timing pulley and the whole phase change mechanism, complete with its actuating system, does not add to the overall length of the engine. The mechanism is furthermore silent and virtually maintenance free.

CLAIMS

1. A phase change element for a phase change mechanism which comprises a disc having cut-outs which are shaped to define a central continuous central portion, an outer continuous rim and a plurality of non-radial spokes extending from the central portion to the rim, all spokes being canted in the same sense whereby movement of the central portion towards and away from the plane of the rim is operative to cause a rotation of the rim relative to the central portion.

2. A phase change element for a phase change mechanism which comprises two or more phase change elements as claimed in claim 1 formed concentrically on a single disc, the disc being divided by cut-outs to define several annuli connected to one another by spokes canted in the same sense, each intermediate annulus constituting the rim of an inner phase change element and the central portion of a surrounding outer phase change element.

3. A phase change element as claimed in claim 1 or 2, wherein the disc is dished in its unstressed state.

4. A phase change mechanism comprising a plurality of phase change elements as claimed in any preceding claim, wherein the discs are stacked front to back and connected to one another alternately at their rims and their central portions.

5. A phase change mechanism having two stacks of discs, arranged on opposite sides of an actuator, one stack being under load when the other is relieved of load.
moves.

6. A phase change mechanism constructed, arranged and adapted to operate substantially as herein described with reference to and as illustrated in the accompanying drawings.

Amendments to the claims have been filed as follows

1. A phase change element for a phase change mechanism which comprises a disc having cut-outs which are shaped to define a central continuous central portion, an outer continuous rim and a plurality of non-radial spokes extending from the central portion to the rim, all spokes being canted in the same sense whereby movement of the central portion towards and away from the plane of the rim is operative to cause a rotation of the rim relative to the central portion.

2. A phase change element for a phase change mechanism which comprises two or more phase change elements as claimed in claim 1 formed concentrically on a single disc, the disc being divided by cut-outs to define several annuli connected to one another by spokes canted in the same sense, each intermediate annulus constituting the rim of an inner phase change element and the central portion of a surrounding outer phase change element.

3. A phase change element as claimed in claim 1 or 2, wherein the disc is dished in its unstressed state.

4. A phase change mechanism comprising a plurality of phase change elements as claimed in any preceding claim, wherein the discs are stacked front to back and connected to one another alternately at their rims and their central portions.

5. A phase change mechanism as claimed in claim 4, having two stacks of discs, arranged on opposite sides of an actuator, one stack being under load when the other is relieved of load.

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